Surface Mount Technology (SMT) Process Specification

DOCUMENT IDENTIFIER: A-SP-ELMF516-00-0000 Rev C, 16-May-1990

ABSTRACT: This specification describes general process requirements for the Surface Mount Module Assembly Process within Digital for releases 1.0, 1.5, and 2.0. Included in this document are requirements for SMT training, documentation, equipment operation, materials, and each step in the production process. Process flowcharts are provided for each SMT release level.

APPLICABILITY: The requirements of this document are mandatory for Digital personnel involved in the design, development, and verification of the Surface Mount Module Assembly Process.

STATUS: APPROVED 16-May-1990; use VTX SMC for current status.

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REVISION HISTORY:	Rev B,	14-Feb-1989	ECO Number CT001
	Rev C,	16-Mar-1990	ECO Number CTS02
Document Management Category:	Modules, Process Related (MAMP)		
Responsible Department:	Technical Resource Group (TRG)		
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APPROVAL: This document has been approved by the technical review group for its category and the Technical Resource Group (TRG).

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this specification is to outline and document process requirements and parameters for each step in the Surface Mount Technology (SMT) process.

The parameters listed in this document specify minimum and maximum acceptable process levels. These requirements are not product-dependent, plant-specific, nor equipment-specific.

Detailed process descriptions are contained in EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

1.2 SCOPE

This specification describes the process requirements for Digital's Surface Mount Module Assembly Process, up to and including the following levels of release.

Release 1.0	Mixed mount: Thru-hole and Surface Mount on one side.
Release 1.5	Mixed mount: Side 1 - Thru-hole and Surface Mount actives, Side 2 - Surface Mount passives.
Release 2.0	Surface Mount on both sides (no Thru-hole).

The three releases noted above have thru-hole leads on a 100-mil standard grid and surface mount components on a 50-mil standard grid consisting of gull-wing, J-Bend configurations, and leadless passive components on Printed-Wiring Board (PWB) substrates, as defined in *DEC STD 176-0 Printed-Wiring Board Acceptance Criteria* and *DEC STD 030-0 Module Manufacturing Standard*.

2 GENERAL REQUIREMENTS

2.1 ENVIRONMENTAL HEALTH AND SAFETY

Processes must comply with the environmental health and safety requirements defined in EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

All equipment safety devices shall be operational.

The following safety and emergency equipment is required.

- Spill cart
- Neoprene, viton, or PVA-coated gloves and aprons
- Disposable coveralls or chemical suits
- Chemical-splash goggles
- Face shield
- Shoe covers
- Full-face negative-pressure respirators
- Self-contained breathing apparatus
- Portable halon extinguisher
- Eyewash station/shower

2.2 TRAINING

All operators shall be trained and certified according to the requirements of their respective areas of responsibility as defined in EL-MF417-00.

2.3 DOCUMENTATION

a. All processes must be fully documented in accordance with *DEC STD 001-0 Management of Technical Standards and Related Documentation*.

b. Detailed requirements for the following documentation are included in EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

- Assembly, test, and inspection procedures
- Equipment specifications
- Material specifications
- Process certification
- Process control
- Process reliability

2.4 OPERATION LIMITATIONS

a. All processes must be capable of handling surface mount devices with or without heat sinks.

Heat sinks limitations are described in *DEC STD 030 Module Manufacturing Standard*.

b. The process shall be capable of handling any printed wiring board (PWB) or module designed in accordance with DEC STD 030. Standard circuit board sizes range from:

3 inches wide x 5 inches long minimum to
12 inches wide x 18 inches long maximum.

c. Standard board thickness may vary from 0.062 to 0.190 inch.

d. Surface mount manufacturing processes require process control; this is detailed in the Surface Mount Manufacturing Process Control Plan and Procedure section of EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

e. The Solder Reflow and Module Cleaning operations must be completed within four hours after Solder Deposition.

f. Process equipment must be maintained and calibrated according to the requirements of EL-MF417-00.

g. System software shall be capable of integration with a Digital host system. This shall include down-line and up-line data loading of controllable parameters with the following objectives.

- Minimizing operator intervention
- Performing statistical process control

h. Product exposed to conditions outside of process limits shall be held for material review board (MRB) disposition.

2.5 MATERIALS

2.5.1 Components

a. All SMT components shall meet the requirements of the applicable Digital general class and/or purchase specifications and EL-MF500-00, *Method for Determining the Solderability of Surface Mountable Packages*.

b. All SMT component leads must have a standard coating of 63/37 to 90/10 tin/lead composition. The coating must have a thickness of 300 microinches.

NOTE

Gull-wing cerquad device leads may have a 100 percent tin coating, matte finish.

c. All dry SMT components must be capable of withstanding the temperature exposure profiles specified in this document, and as shown in Figure 1. Note that Figure 1 shows approximate profiles; specific temperature parameters are defined under heading 4.

d. All high pin count SMT components (68 pins and higher) that are packaged in plastic carriers shall contain less than 1000 PPM moisture content just prior to assembly onto a printed wiring board. Methods and procedures for ensuring component dryness are detailed in EL-MF417-00.

2.5.2 Modules/Boards

a. Board quality shall be in accordance with *DEC STD 176-4 Surface Mount Printed-Wiring Board Acceptance Criteria*, including SMT process compatibility requirements.

b. Completed module quality shall be in accordance with EL-SM116-01, *Workmanship Standards Manual - Volume 1*.

c. All modules shall be designed in accordance with the requirements of DEC STD 030.

2.5.3 Process Materials

All process materials shall meet the requirements of applicable specifications.

The following profiles illustrate approximate component temperatures during the Surface Mount process. Note maximum temperature, time at specified temperature, and cycles of exposure. Refer to heading 4 for specific temperature profiles.

Figure 1: Component Temperature Profiles

Figure 1. Component Temperature Profiles (continued)

2.6 MATERIAL HANDLING

Surface mount technology material handling shall have the following attributes.

a. Shall be compatible with the Thru-hole module process.

b. Must not have a detrimental effect on such product quality criteria as component location, component or board physical condition, and/or solder mechanical bond.

c. Must not induce excessive jarring or vibration that could dislodge, move, or impact components or solder joints at any step in the process.

d. All stations, operators, and equipment shall be electrostatically grounded and protected according to the requirements of *DEC STD 067-0 Handling of Electrostatic Sensitive Devices - Procedures and Protective Materials*.

e. Should provide for random access (flexible routing) between work cells.

f. Should be flexible enough to accept capacity and mix changes.

g. Shall provide First-In-First-Out rotation (FIFO) for all parts, materials, and assemblies.

h. Should have product tracking and data collection capability.

i. All components for shipment to Digital shall be packaged according to the requirements of EL-MF531-00, *General Specification for Taping Surface-Mounted Components*.

2.7 QUALITY AND RELIABILITY

a. The process shall not induce quality or reliability defects.

b. The quality program shall focus on defect prevention.

c. Modules must meet specific product and process specifications and all applicable Digital standards and Engineering Specifications.

d. Appropriate quality data must be gathered (preferably automatically) and relayed to the appropriate stations/individuals.

e. Solder joints shall be tested for Surface Mount process reliability in accordance with EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

f. It is recommended that the SMT Process achieve process certification as defined in EL-MF417-00.

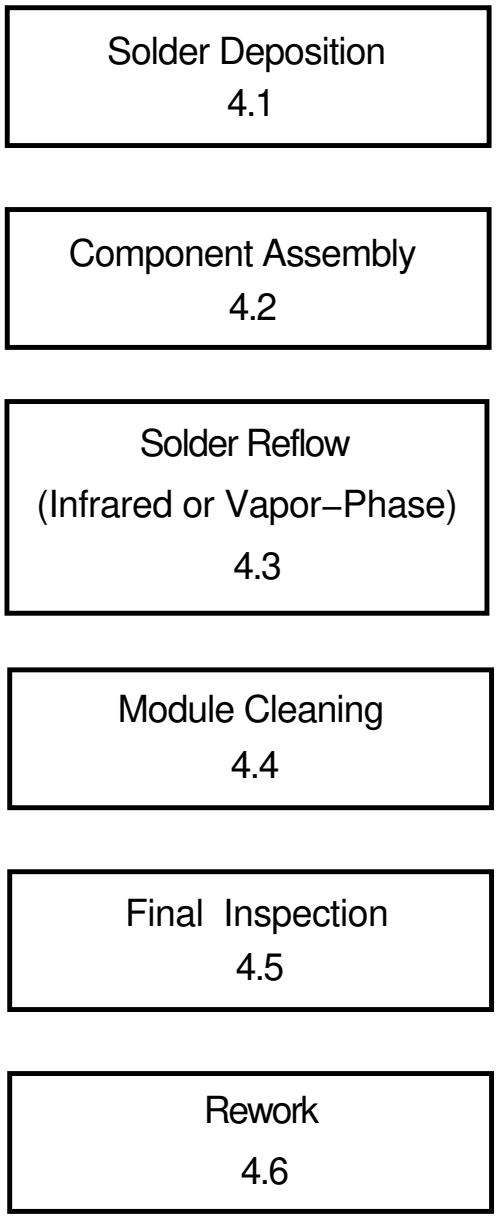
2.8 PROCESS METRICS

a. Assembly defects (incorrect component selection or component misalignment, misorientation, or damage) shall not exceed 50 parts per million (PPM).

b. Solder joint defects shall not exceed 10 PPM.

3 SMT PROCESS

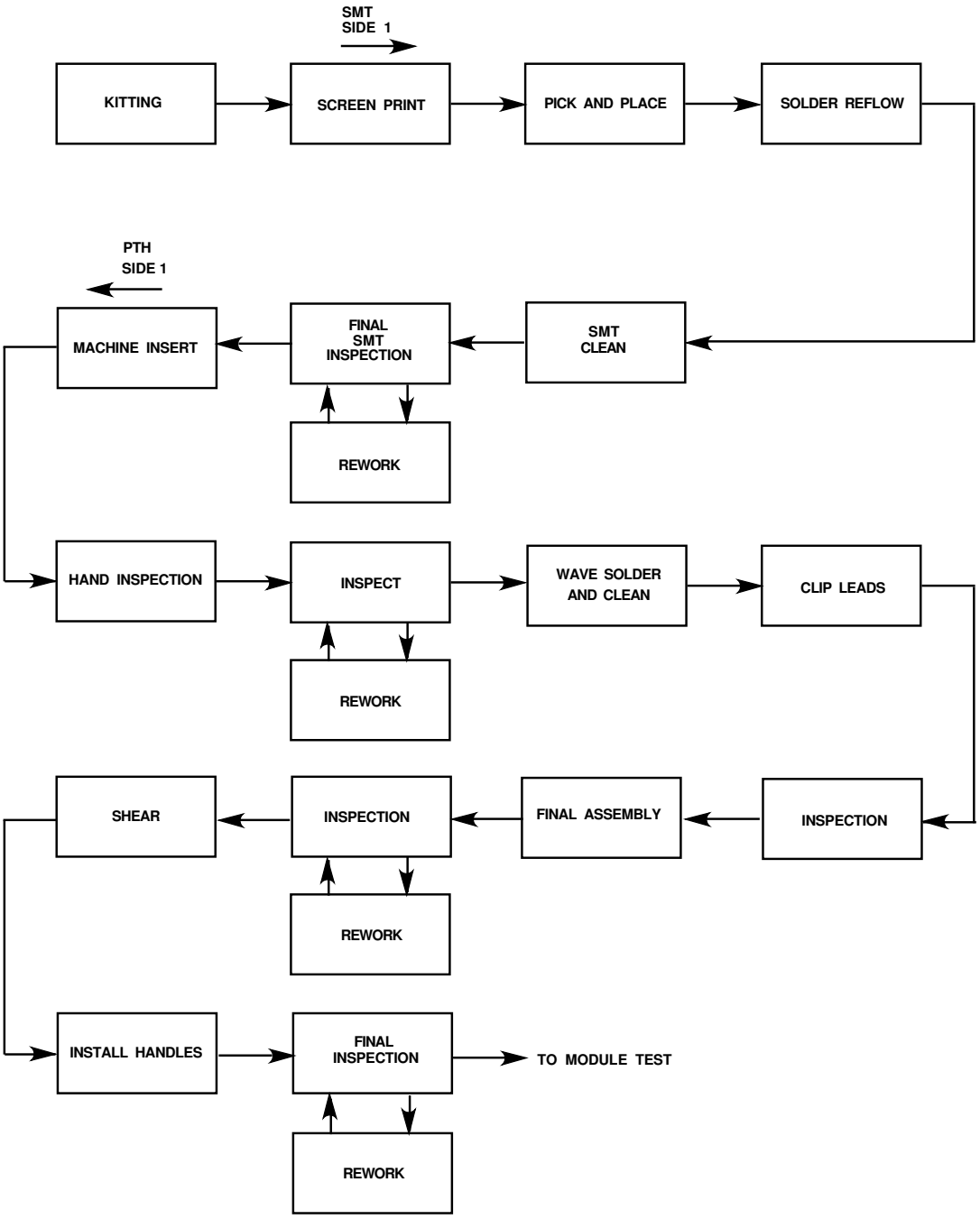
The surface mount process consists of the following macro-process steps. Numbers listed refer to the subhead describing requirements for that process step.



Detailed flow charts for each release level of the above general SMT process are shown on the following pages.

3.1 FLOW CHART OF RELEASE 1.0

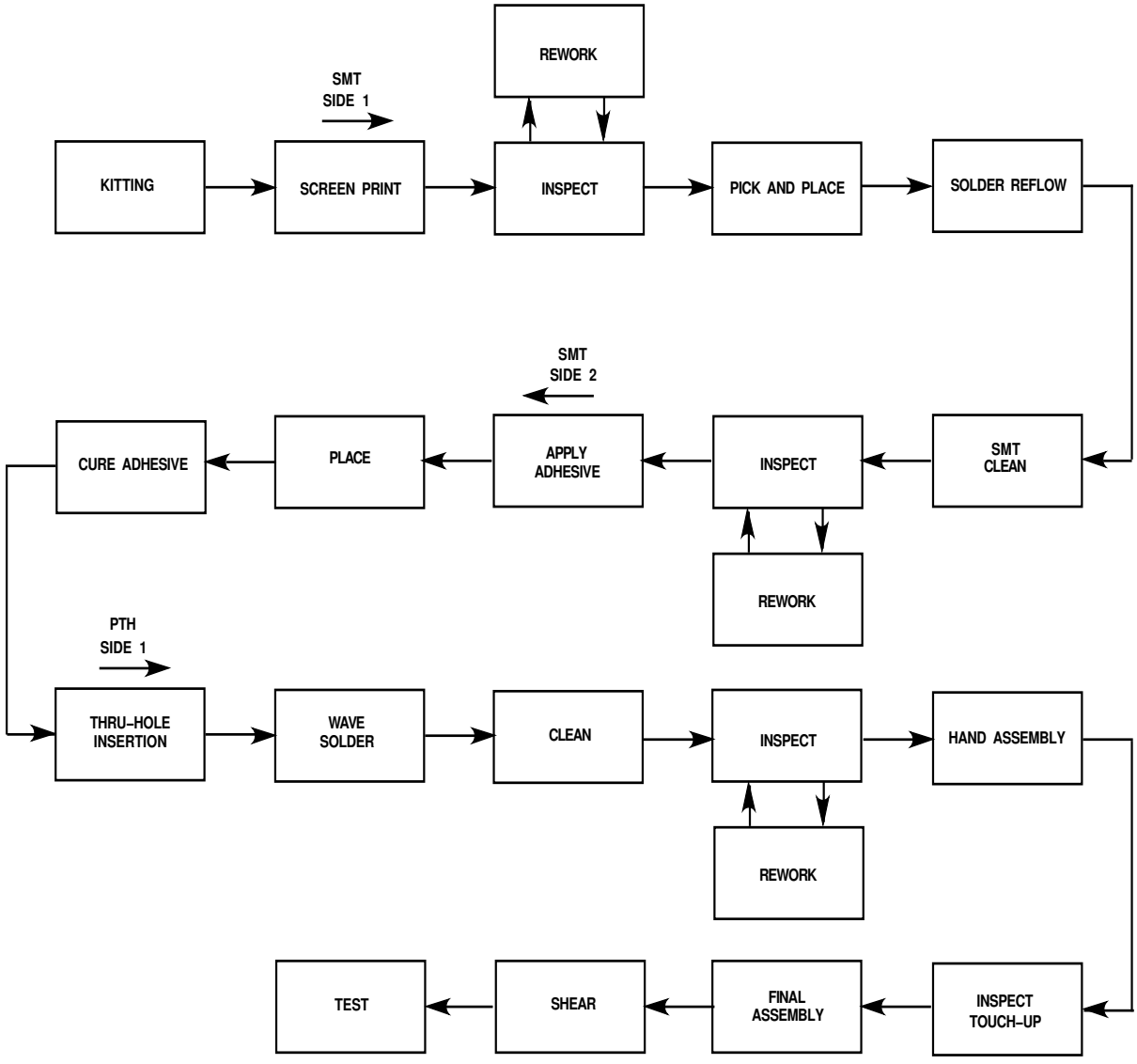
MIXED MOUNT: THRU-HOLE AND SURFACE MOUNT ON ONE SIDE



3.2 FLOW CHART OF RELEASE 1.5

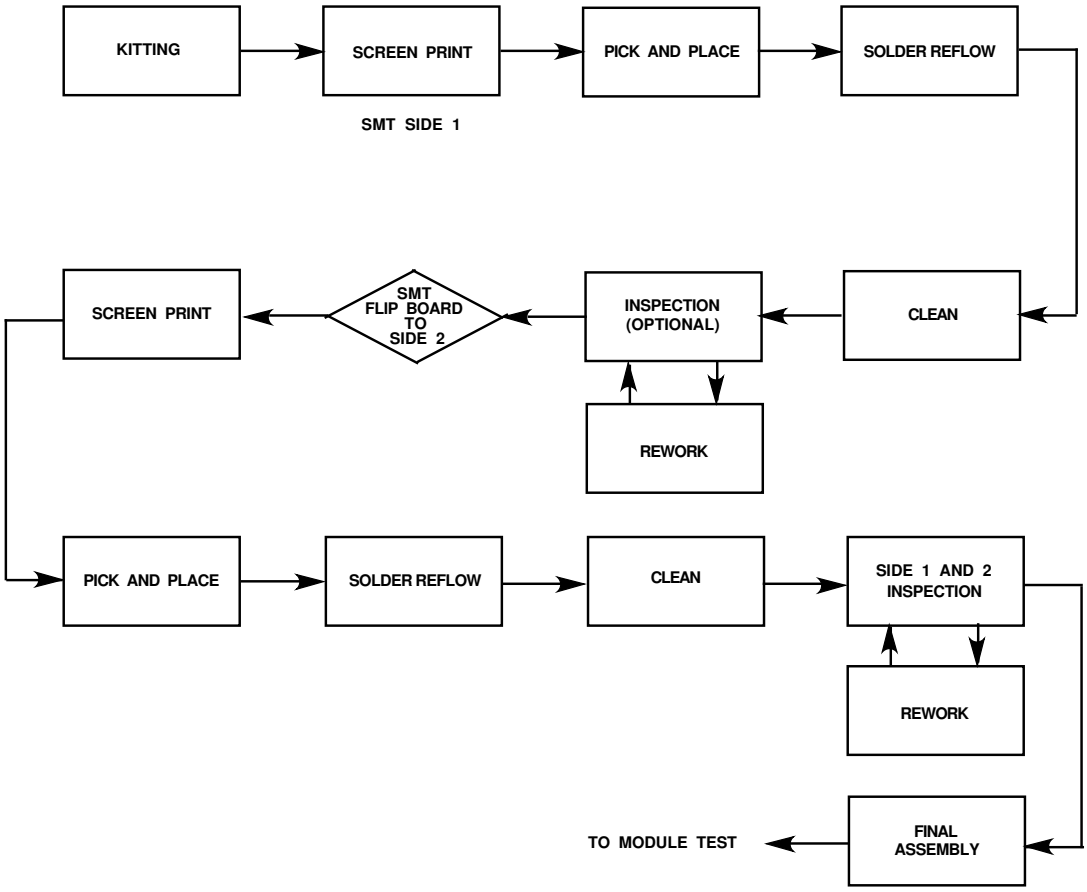
MIXED MOUNT:

SIDE 1 - THRU-HOLE AND SURFACE MOUNT ACTIVES
SIDE 2 - SURFACE MOUNT PASSIVES



3.3 FLOW CHART OF RELEASE 2.0

SURFACE MOUNT ON BOTH SIDES



4 REQUIREMENTS BY PROCESS STEP

4.1 SOLDER PASTE DEPOSITION

Operation Limitations

a. Recommended stencil thickness:

   0.005 inch ± 0.001 inch for 25-mil lead pitch.

   0.010 inch ± 0.001 inch for 50-mil lead pitch (up to 84 leads).

b. Maximum acceptable board warpage: Refer to *DEC STD 176-4 Surface Mount Printed-Wiring Board Acceptance Criteria*.

c. Solder Reflow and Module Cleaning must be completed within four hours after application of solder paste to a Printed-Wiring Board (PWB).

Process Control Requirements

a. Deposited paste thickness:

   0.006 inch ± 0.002 inch for 25-mil lead spacing.

   0.012 inch ± 0.002 inch for 50-mil lead spacing.

b. Paste to pad misregistration accuracy: maximum 25 percent off pad.

c. PWB holding fixture flatness: ± 0.001 inch.

d. Visual inspection criteria: Missing, excess, smeared, or misregistered paste and/or paste tails are rejectable conditions.

e. Use X bar and R statistical process control techniques for controlling paste thickness.

f. Use percent yield statistical process controls.

Equipment Parameters

a. Snap-off: 0.015 inch minimum distance between stencil and board.

b. Recommended squeegee hardness: Standard 80 durometer.

c. Squeegee force: 25 inch-pounds or as required to achieve even solder deposition across board.

d. Squeegee speed: 1 inch/second ± 10 percent.

e. Product specific fixture shall be designed so that the minimum PWB thickness will be flush with the fixture's top surface.

   Cavity depth shall not exceed minimum PWB thickness.

Health and Safety

Personal protective equipment required:

a. Latex rubber gloves must be worn by operators at all times.
b. Neoprene, Viton, or PVA-coated aprons must be worn by operators at all times.
c. Chemical splash goggles (OSHA 1910, Z87.1) must be worn when cleaning stencils.

Other safety requirements:

a. No eating, drinking, or smoking allowed.
b. Local ventilation must be operating according to applicable design specification.
c. Wash hands before leaving area.

Materials

For solder paste requirements, refer to EL-MF417-00, *Surface Mount Technology (SMT) Reference Manual*.

4.2 COMPONENT ASSEMBLY

Operation Limitations

a. Component packaging shall be limited to tubes/magazines, matrix trays, and tape-and-reel devices.

b. Component placement must occur within the four hour limit between Solder Deposition and Vapor-Phase Solder Reflow/Module Cleaning.

Process Control Requirements

a. Components shall be positioned in accordance with *DEC STD 116-9 Workmanship Standards Manual - Surface Mount*.

b. Visual inspection and/or verification criteria: Incorrect device, misorientation or misalignment, or component damage.

c. Use percent yield statistical process controls.

Equipment Parameters

The component assembly system shall have the following attributes.

a. Work area: 12 x 18 inches minimum.

b. Capable of mounting surface mount devices on both sides of the PWB.

c. Device feed mechanism shall be compatible with all of the above packaging types.

d. Machine vision rezero: The system shall be able to recognize and process fiducial data (PWB and/or component level visual reference targets) for placement accuracy.

e. Capable of up and down-line data loading.

f. Capable of handling the full range of components (refer to subhead 1.2).

g. Capable of force sensing during component placement.

h. Controllable X, Y, and Z axes.

i. Placement accuracy for lead to solder pad at point of onsertion shall fall within the following formula.

(D/Dmax) + (DT/DTmax) = 1, where

T = Theta
D = Distance between pad and lead center lines

Dmax = 1/2 Wp - (F - (1/2 Wl)), where

F = Fractional overlap (minimum acceptable) 0.0075 inch.
Wl = Width of any lead range: 0.0105 to 0.0145 inch.
Wp = Width of pad range 0.014 to 0.016 inch.

DTmax = (2Dmax)/Lc, where

Lc = Maximum length of component from lead center to lead center (opposite sides)

Health and Safety

No eating, drinking, or smoking allowed. All equipment safety devices shall be operational. Latex rubber gloves shall be worn by operators when loading and unloading PWBs.

4.3 SOLDER REFLOW

This subhead specifies parameters and requirements for both Infrared (IR) Solder Reflow and Vapor-Phase Solder Reflow operations. The following thermocoupling guidelines apply to temperature profiling for either solder reflow operation.

Thermocouples must be placed as follows.

a. For gull wing devices:
   1. Unsolder and lift a component lead, place the thermocouple wire on the board, bring the lead down between the two thermocoupling wires, and solder it back in place.
   2. Cover the joint with high temperature epoxy or use high temperature solder. Use only enough solder or epoxy to prevent the thermocouple from reading air temperature, but do not insulate the thermocouple.

b. For J-Bend devices: Wedge the thermocouple head between two leads and cover as specified in item (a).

c. For small discrete devices: Solder the thermocouple between two devices or to the end pad of one device and cover as specified in item (a).

d. For the laminate: Secure the thermocouple directly to the laminate with epoxy.

4.3.1 Infrared Solder Reflow

Operation Limitations

a. Infrared solder reflow must occur within a four hour limit after solder paste deposition.

b. Solder joint characteristics must conform to the time and temperature profile shown in Figure 2.

c. Solder must be solidified prior to removal from equipment.

Process Control Parameters (IR Profile Specification)

Temperature limits are as follows.

a. Maximum rate of temperature rise and cool down: 2°C/second.

b. Minimum dwell time between 150 and 183°C: 60 seconds.

c. Solder joint temperature at reflow: 215°C ± 10°C.

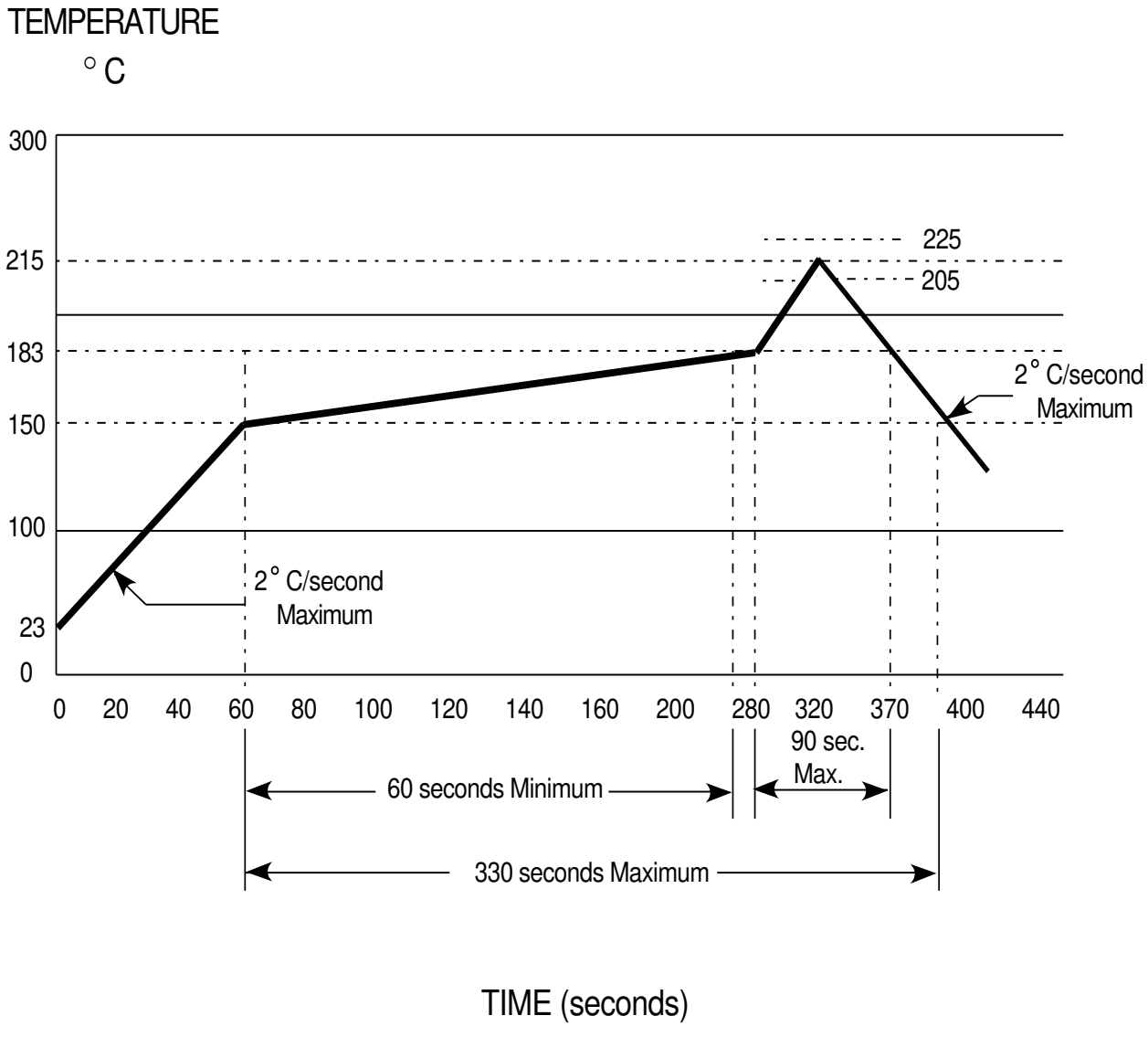
d. Maximum time above 183°C: 90 seconds.

e. Maximum time at or above 150°C: 330 seconds.

NOTE

For single or double-sided boards, at peak reflow temperatures, all thermocouple readings must be at 215 ± 10°C on the reflowed side.

Figure 2: Infrared Reflow Temperature Profile (Profile Specification)



Infrared Reflow Profile Development

1. For single-sided boards:

   Using a board containing SMT components only (and representing the actual product), place thermocouples in the following places to obtain required temperature data.

   a. Leading edge of the board laminate.

   b. Trailing edge at a low-density area, on the lead of any small outline transistor (SOT), chip capacitor, or resistor.

   c. Board center, on a component lead.

   d. High-density area, on a component lead. **Note:** If the high-density area is in the center of the board, do not place an additional thermoucouple in the board center. The thermocouple required by item c (above) will provide the required temperature reading.

   e. A large heat-sink area of board, on a component lead. For example: a component lead on the edge of the PWB, near a rail conveyor.

2. Double-sided SMT boards (two required):

   a. Board 1, Side 1, Populated: Same as number 1 (above).

   b. Board 1, Side 2, Not populated: No thermocouples required.

   c. Board 2, Side 1, Populated: Place a separate thermocouple on a component lead, in both high and low-density areas.

   d. Board 2, Side 2: Minimum of three thermocouples required, placed in the following locations.

      - Laminate
      - Small component lead (low-density area)
      - Large component lead (high-density area)

NOTE

It is recommended that 30 gauge (AWG), K-type thermocouple wire be used.

Compliance Requirements

Compliance with the Infrared Profile must be verified under the following static and dynamic equipment conditions.

a. Static condition (cold oven start):

   Using a thermocoupled board as described in subhead 4.3.1, obtain two profiles within 2° C at all thermocouple locations.

b. Dynamic condition:

   After the oven has stabilized under static conditions, load the tunnel for 15 - 30 minutes with scrap boards spaced at intervals of one board length and run the thermocoupled board again. The temperature readings at all thermocouple locations must be within the limits of the profile specification (see subhead 4.3.1 and Figure 2). When the profile is achieved, the oven has reached stabilized dynamic condition.

   This procedure need not be repeated for every product, but must be performed when a new oven is obtained. Verification should also be performed periodically to ensure proper oven performance and to determine any performance characteristics that may affect volume production.

Note that for production profiling, the oven must be at a stable dynamic condition before production begins. The time required to reach stable condition will depend on the characteristics of each oven. It is also the responsibility of the Manufacturing Engineer at each plant to define the time required for the oven to reach a stable condition when changing profiles.

Equipment Parameters

Equipment used in the Infrared Reflow process:

a. Must have proper ventilation and exhaust ducting.

b. Must not induce any vibration that could dislodge, move or impact the alignment of the components to pads or the integrity of the solder joint at any step in the process.

c. Must maintain modules in a horizontal plane.

d. Refer to infrared equipment functional specifications for further details.

Health and Safety

a. Heat-resistant gloves required.

b. No eating, drinking or smoking allowed in the area.

c. Warning sign for hot surfaces above 50°C.

4.3.2 Vapor-Phase Solder Reflow Process

This subhead provides requirements and parameters for the two steps in the Vapor-Phase Solder Reflow Process: Paste Dry and Flux Activation and Vapor-Phase Solder Reflow.

4.3.2.1 Paste Dry and Flux Activation

Operation Limitations

a. Paste Dry and Flux Activation must occur within the four hour limit between Solder Deposition and Vapor-Phase Solder Reflow/Module Cleaning.

b. Solder joints characteristics must conform to the time and temperature profile shown in Figure 3.

c. Modules must be transferred to the Vapor-Phase Solder Reflow operation immediately after Paste Dry and Flux Activation is completed.

Process Control Requirements

The following are key points from Figure 3.

a. Solder paste temperature: 150 degrees Celsius (°C) ± 10°C.

b. Paste drying time: Minimum 120 seconds to maximum 180 seconds.

c. Using a thermocoupled module (representing the actual product):

   1. Establish equipment parameters for module.

   2. Set up and verify equipment parameters. See subhead 4.3 for thermocoupling procedures.

d. Minimum solder joint temperature at entry to Vapor-Phase Solder Reflow: 130°C.

Equipment Parameters

The equipment used in the Paste Dry and Flux Activation process:

a. Must have proper ventilation.

b. Must not induce excessive jarring or vibration that could dislodge, move, or impact components or solder joints at any step in the process.

c. Must maintain modules on a horizontal plane.

Health and Safety

Personal protective equipment required:

a. Latex rubber gloves shall be worn when loading modules into machine.

b. Heat resistant gloves shall be worn when unloading modules.

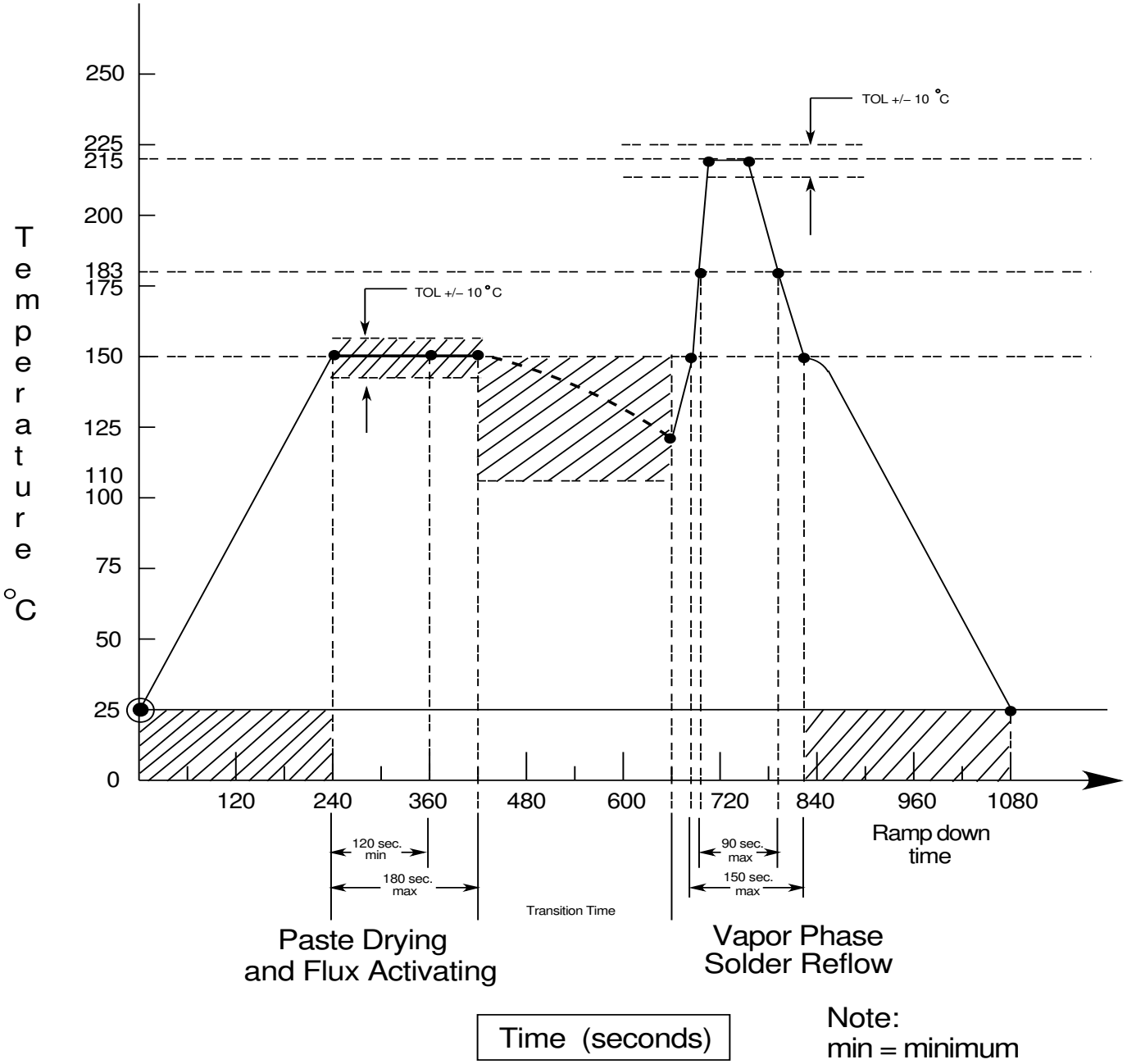
Other safety requirements:

a. No eating, drinking, or smoking allowed.

b. Local ventilation must be operating properly when using paste.

c. Wash hands before leaving area.

Figure 3: Vapor-Phase Solder Reflow Temperature Profile



4.3.2.2 Vapor-Phase Solder Reflow

Operation Limitations

a. Vapor-Phase Solder Reflow must occur within the four hour limit between Solder Deposition and Module Cleaning.

b. This operation requires immediate input of modules from the Paste Dry and Flux Activation step (subhead 4.3.2.1).

c. Solder joints characteristics must conform to the time and temperature profile shown in Figure 3.

d. Solder must be solidified prior to removal from equipment.

Process Control Requirements

The following are key points from Figure 3.

a. Minimum temperature of module entering Vapor-Phase Solder Reflow: 110°C.

b. Maximum temperature module is exposed to shall not exceed 225°C.

c. Maximum time of exposure above 150°C: 150 seconds/side.

d. Maximum time of exposure above 183°C: 90 seconds/side.

e. Using a thermocoupled module (representing actual product):

   1. Establish equipment parameters for module.
   2. Set up and verify equipment parameters.

Equipment Parameters

The equipment used in the Vapor-Phase Solder Reflow process:

a. Must maintain a level vapor consistency.

b. Must have proper ventilation. The system must be designed so as not to effect vapor consistency.

c. Must not induce excessive jarring or vibration that could dislodge, move, or impact components or solder joints at any step in the process.

d. Must maintain modules on a horizontal plane.

e. Must have a cooling section to accommodate solder solidification.

Health and Safety

Personal protective equipment required:

a. Heat-resistant gloves.

Other requirements:

a. No eating, drinking, or smoking allowed.

b. Warning sign for hot surfaces.

c. Ventilation system must automatically turn on when machine is turned on, and turn off by temperature controls.

d. Monitor for vapor leaks.

4.4 MODULE CLEANING

Operation Limitations

The maximum product environmental (chemical) exposures are as follows.

Type	Temperature	Time
Aqueous Wash	66° C	240 seconds
Aqueous Dry	121° C	250 seconds
Solvent after repair	Cold	4-6 seconds

Process Control Requirements

a. Visual inspection requirements:

   No visual contamination on the module after cleaning.

b. Contamination thresholds:

   Testing to the requirements of EL-MF299-00, *Printed-Circuit Boards/Modules: Cleaning Process Contamination*.

Equipment Parameters

a. Wash tank temperature: 66°C. ± 3°C.
b. Wash tank concentration: 5 to 8 percent.
c. Adjustable conveyor speeds (product-dependent).

Health and Safety

Personal protective equipment required:

a. Lab coats or smocks.
b. Neoprene, Viton, or PVA-coated gloves and aprons.
c. Chemical splash goggles.
d. Heat-resistant gloves.

Other requirements:

a. No eating, drinking, or smoking.
b. Local ventilation must be operating according to applicable design specification.
c. Wash hands before leaving area.

4.5 FINAL INSPECTION

Operation Limitations

a. Accept/reject criteria in accordance with EL-SM116-01, *Workmanship Standards Manual - Volume 1*.

b. Additional or alternate inspection criteria must be supplied in writing by Quality Engineering.

c. Inspectors must be trained/certified for Surface Mount inspection.

Process Control Requirements

a. Inspection/verification shall be performed on 100 percent of the solder joints on 100 percent of the modules processed.

   Minimum solder joint inspection criteria shall include the following.

   1. Opens
   2. Solder bridging (shorts)
   3. Solder integrity
   4. Solder balls
   5. Cold solder joints
   6. Insufficient solder
   7. Missing solder

   Other visual inspection criteria shall include the following, at a minimum.

   1. Lead misalignment
   2. Damaged or cracked components/modules
   3. Cleanliness/contamination

b. Using the latest revision of the appropriate module assembly drawing, verify that the correct components are in their required location and correct orientation.

c. Use percent yield statistical process controls.

Equipment Parameters

The microscope/magnifying device used must have minimum 10X magnification.

Reliability Impact

a. The inspection/verification of 100 percent of all solder joints is required to prevent Solder Joint Reliability Infancy failures.

b. Sampling plans that meet PPM/infancy risk requirements may be developed for the inspection/verification of solder joint integrity.

4.6 REWORK - COMPONENT REMOVAL AND REPLACEMENT

Operation Limitations

a. The rework operation shall be performed in accordance with *DEC STD 265-0 Module Rework and Repair - Standard Procedure*.

b. Module Cleaning shall be performed after any rework procedure.

Process Control Requirements

a. Maximum temperature: 250°C.

b. Maximum time: 2.5 minutes (forced air).

c. Placement as defined in Subhead 4.2.

d. Protect adjacent components.

e. Visual inspection criteria: Incorrect device, orientation, or alignment, component damage, and solder joint integrity.

Health and Safety

Personal protective equipment required:

a. Heat-resistant gloves.

b. Lab coats or smocks.

c. Goggles.

d. Local ventilation must be operating properly.

Other requirements:

No eating, drinking, or smoking allowed.

APPENDIX A REFERENCED DOCUMENTS

A.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-00001-00	*DEC STD 001-0 Management of Technical Standards and Related Documentation*
EL-00030-00	*DEC STD 030-0 Module Manufacturing Standard - Introduction and General Information*
EL-00067-00	*DEC STD 067-0 Electrostatic Discharge - Sensitive Devices*
EL-00116-09	*DEC STD 116-9 Workmanship Standards Manual - Surface Mount*
EL-00176-00	*DEC STD 176-0 Printed-Wiring Board Acceptance Criteria*
EL-00176-04	*DEC STD 176-4 Surface Mount Printed-Wiring Board Acceptance Criteria*
EL-00265-00	*DEC STD 265-0 Module Rework and Repair Standard Procedures*
EL-MF417-01	*Surface Mount Technology Reference Manual - 2 Volume Set*
EL-MF417-02	*Surface Mount Technology Reference Manual - Volume 2*
EL-MF434-00	*Hart (Hot Air Repair Terminal) 200 and 200-A Operational Procedure*
EL-SM116-01	*Workmanship Standards Manual - Volume 1*
EL-MF299-00	*Printed-Circuit Boards/Modules: Cleaning Process Contamination*
EL-MF500-00	*Method of Determining the Solderability of Surface Mountable Packages*
EL-MF531-00	*General Specification for Taping Surface-mounted Components*

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